Raman Lidar
Observations of Lifting at a Convergence Line

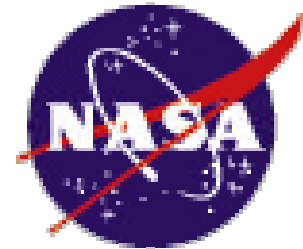## B. Demoz, K. Evans

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Outline

- Boundary Layer Convergence Lines (BLCL):
  - *What* are they and *Why* are they important?
  - What is needed to forecast BLCL?

- Raman lidars can be used to study BLCL:
  - *How* are they used?
  - Case study - 28 September 1997
    - Synoptic overview
    - Wind information
    - Raman lidar data
      - Water vapor data
      - Cloud base height information
    - Ancillary data: other remote sensing instruments?

- Theoretical implications
- Summary

What are Boundary Layer Convergence lines (BLCL)?

Opposing flows in the Boundary layer leading to convection.

How important are BLCL lines?

- lead to "Moisture Lifting" which leads to clouds and storms

- Convective storms form near BLCL

  (see Wilson and Schreiber, 1986, BAMS)

  – 75% of all storms (in Colorado)

  – 95% of intense storms

- Rainfall is correlated to low-level wind convergence

  (see Byers and Rodebush, 1948;

  Watson and Blanchard, 1984)
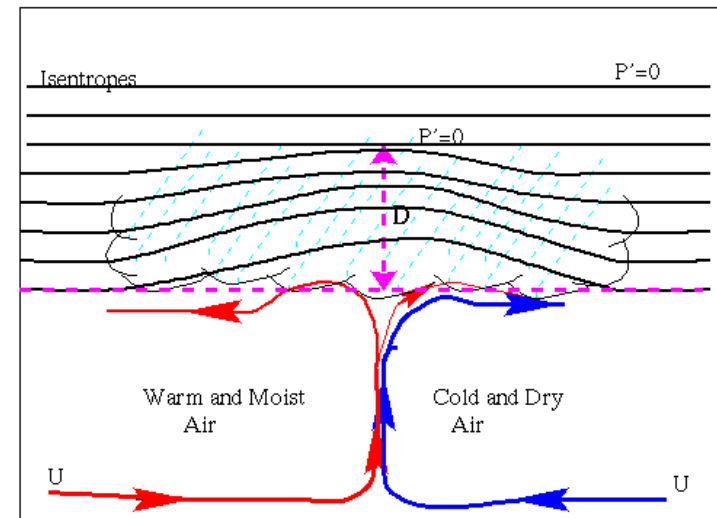
BLCL are key to understanding cloud and storm dynamics as well as forecasting these systems.
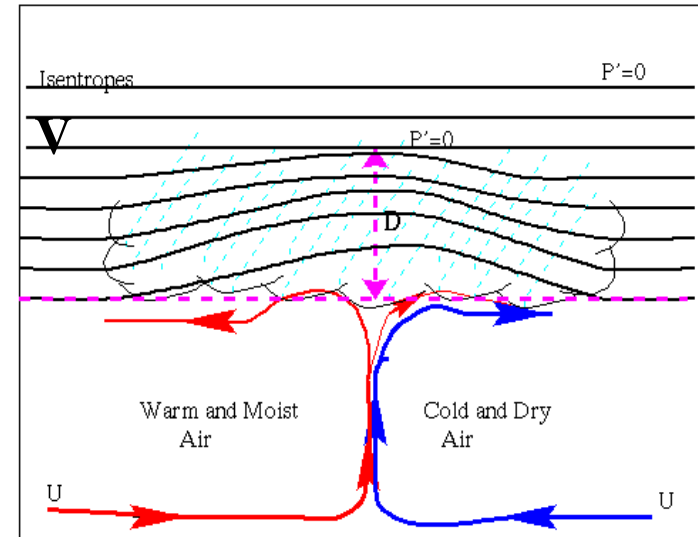
What is needed to Forecast BLCL?

- D displacement (or lifting depth d_{max})
- V is speed above the boundary layer
- U relative speed of colliding flows
- N is Brunt-Vaisala frequency above BLC

Theoretical Prediction of D?
    - works for V/U > 1
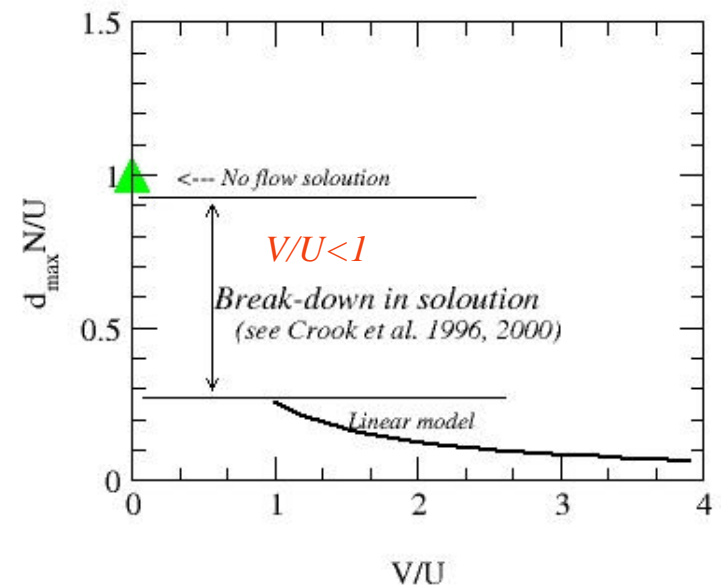   - works for *No-Flow* above BLC
    - fails if V/U < 1!!

Observation should
    1) fill where theory fails and
    2) test the validity of the theory

Theoretical Background
(see Crook and Klemp, 2000,JAS)

What we need from observation:

– Is there a BLC?

– Will it form clouds (How high is moisture lifted)?

– Why is there? (Dynamics of the lifting?)

How can Raman lidars be used?

- Water vapor is conserved
- Wind and vapor are correlated
} *Visualize the dynamics*

- Aerosol backscatter

(see *Demoz et al. 2000, GRL*)
- Liquid water is possible
(see *Whiteman et al 1999, JGR*)
} *Lifting depth derived from cloud base*

Raman Lidars used in this study:

- The GSFC Scanning Raman Lidar (or SRL)

(see *Whiteman et al, Evans et al, ILRC2000)*

- DOE/ARM Raman Lidar (or CARL)

(see *Turner et al, ILRC2000)*
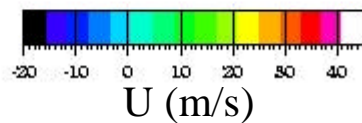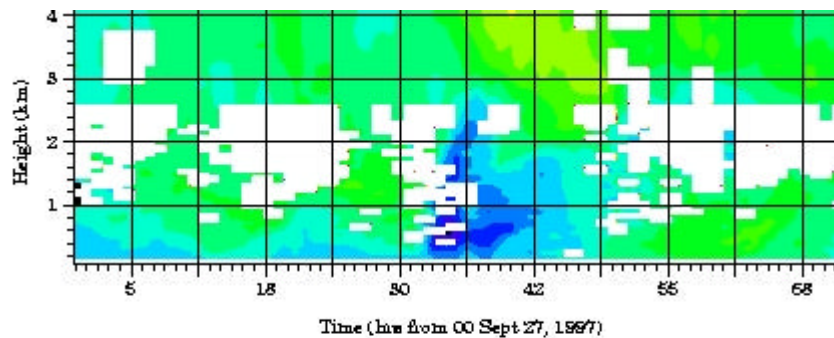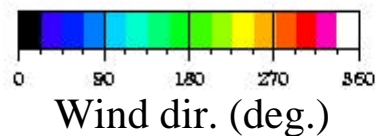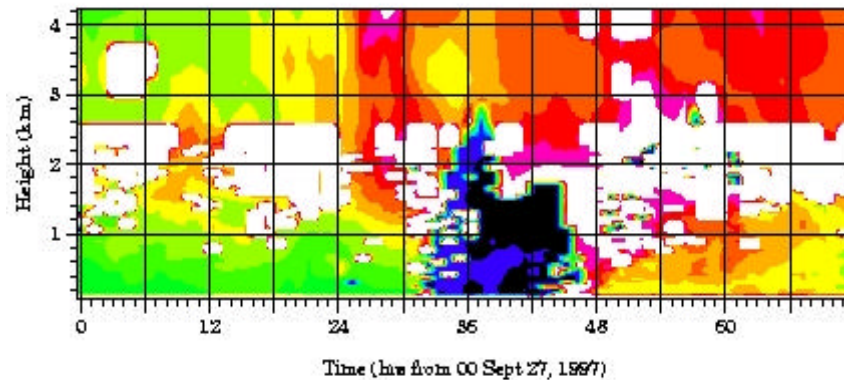
CASE STUDY:

28 September 1997 at CART, Oklahoma (USA)
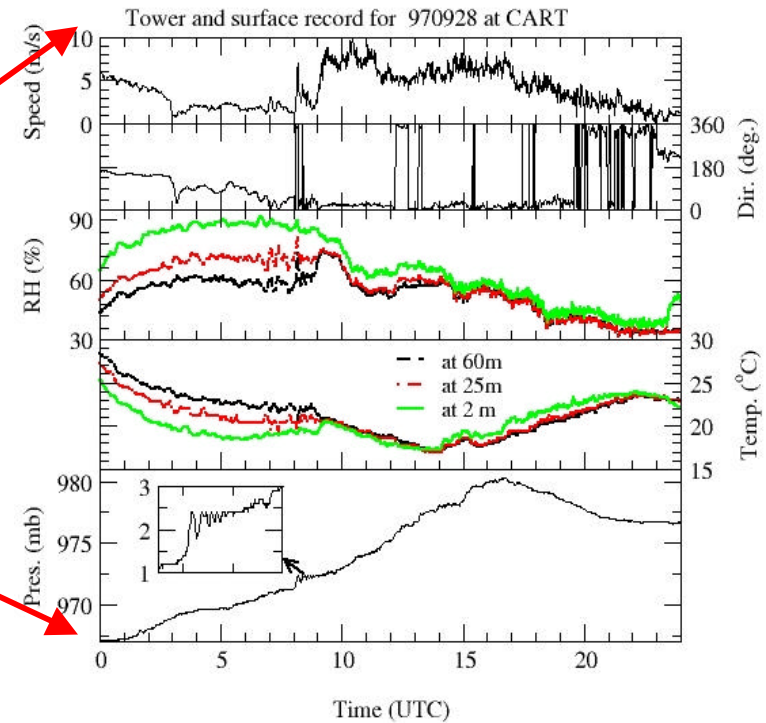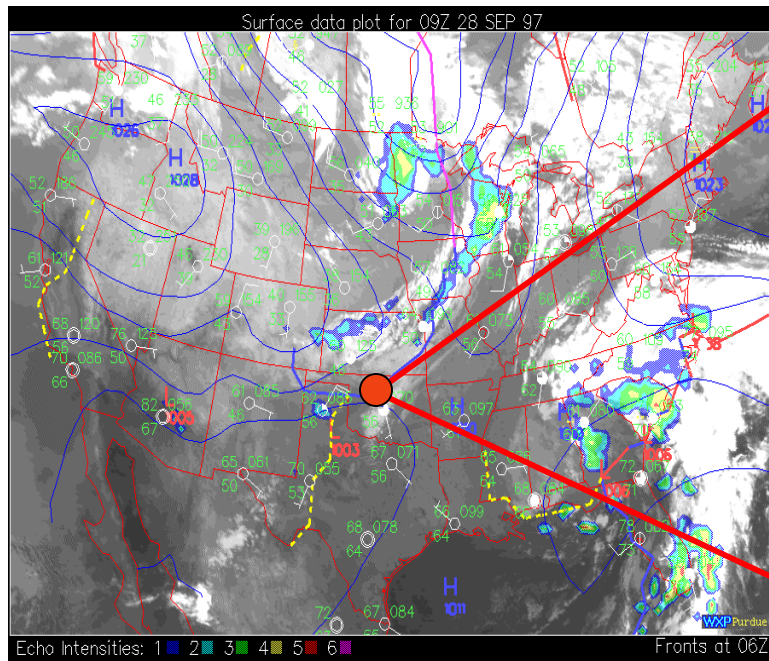
- Moist/warm pre-frontal air-mass

- Cold frontal air-mass

Provided the colliding flows for BLCL

Wind Information: (50 and 915 MHz Profilers)

Wind dir. (deg.)

U (m/s)

Wind summary:
[50 MHz (2-12 km) & 915 (1-5km)]

Pre-front
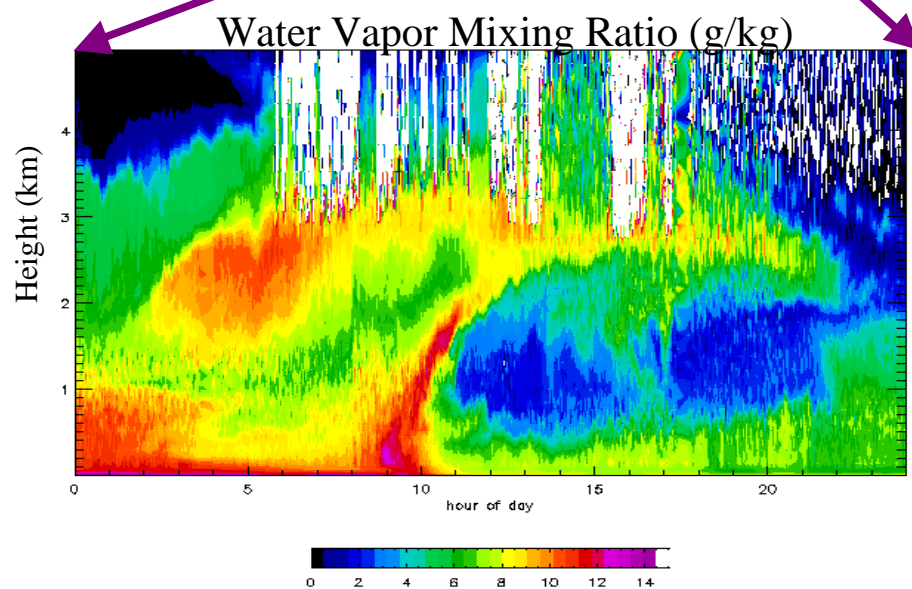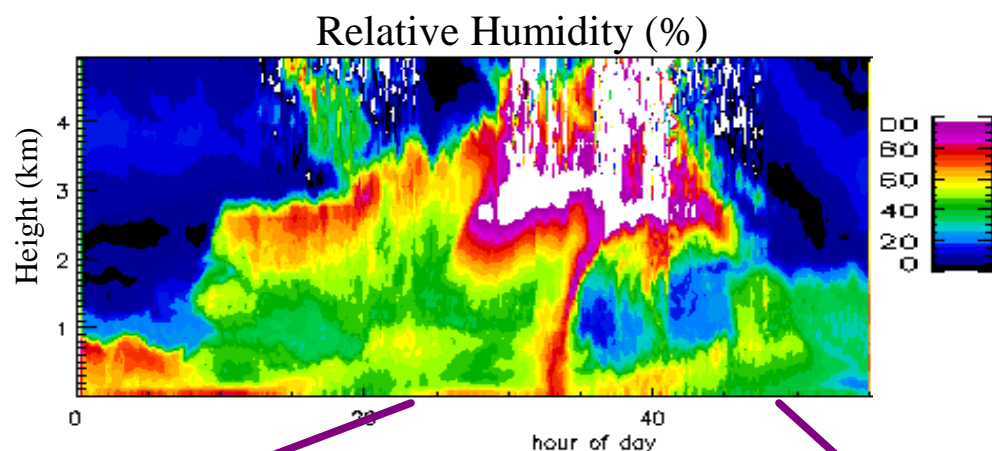 Wind Direction: 180^0
  Wind Speed: 5 to 10 m/sec

Post-front
  Wind Direction: 0^0-10^0
  Wind speed: 5 to 10 m/sec

Wind conditions for boundary layer convergence were roughly met!

CARL Water Vapor Mixing Ratio and RH Data:

Relative Humidity (%)

Water Vapor Mixing Ratio (g/kg)

Time (UTC) ----->

Water Vapor Summary:

Day and night operation

Moisture "lifting" detailed
(continuos operation)

Moisture transitions detected
(Note the narrow convergence line!)

Cold-front structure revealed

*Boundary Layer Convergence
Line dynamics visualized!!*

We needed to know
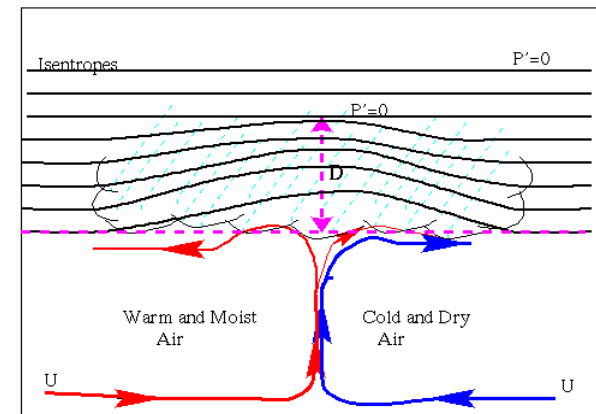
Is there a BLCL?

Will it form clouds (how high is moisture lifted)?

Why is there? (Dynamics of the lifting?

So far, we have shown

- Opposing flows (Profiler)
- Low level moisture (Raman Lidar)
- Lifting or cloud formation (Raman Lidar)
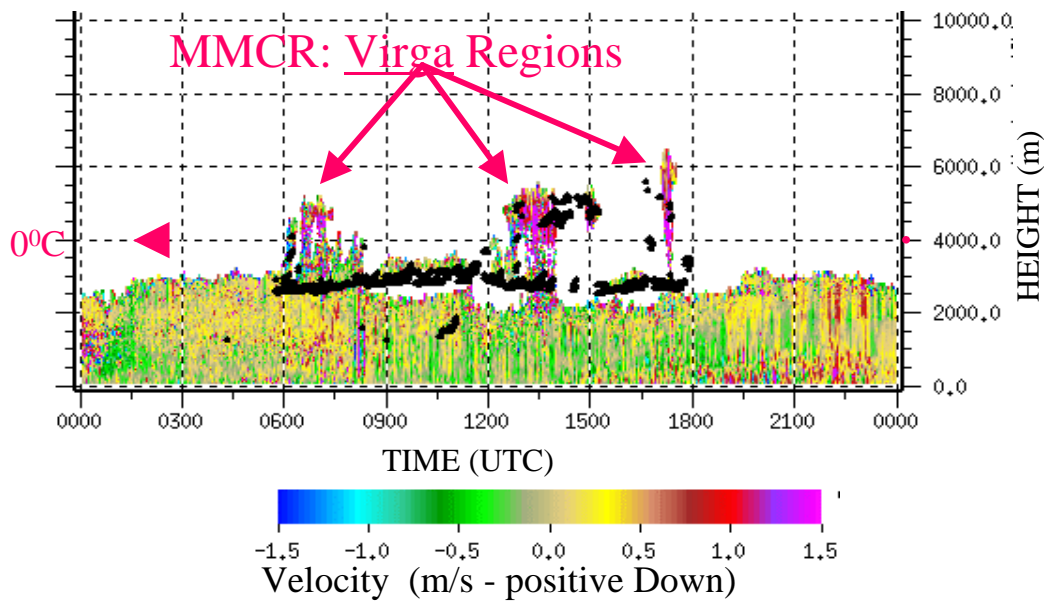- Brunt-Vaisala frequency, N (3-hr Sonde)
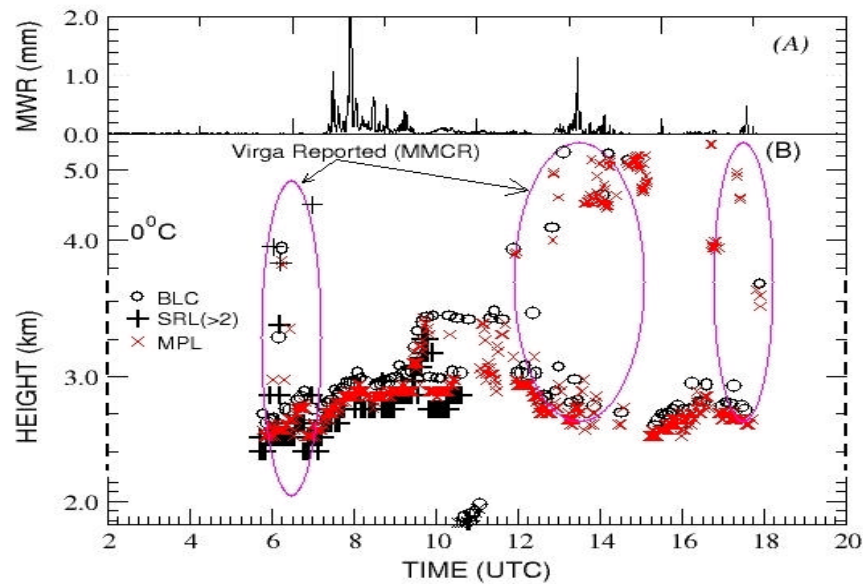
We still need to know

- Lifting, How high (d_max)?

Assumption:

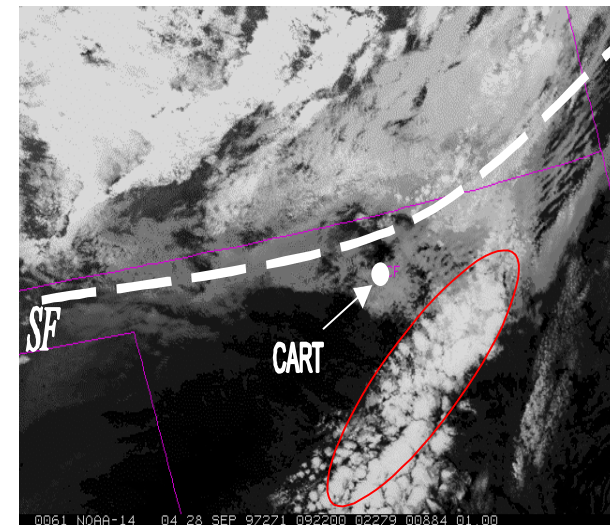*We will assume cloud base height can be used as an indicator for the lifting depth.*

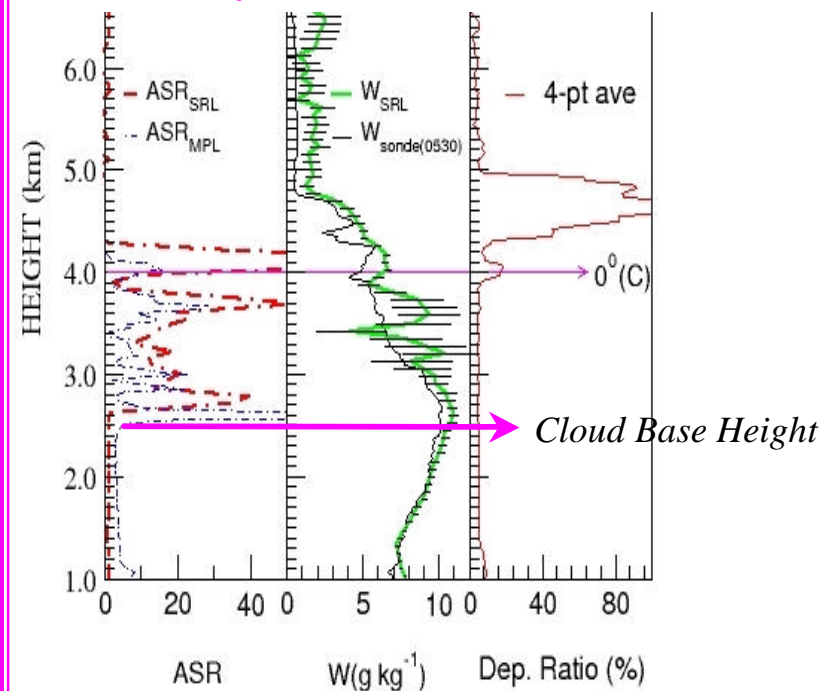*How well can the Raman lidars detect Cloud Base Height?*

SRL/CARL Cloud Base Heights:

Cloud Base Height

MMCR: Virga Regions

Velocity (m/s - positive Down)

• *From Belfort Laser Ceilometer*

SRL/CARL Cloud Base Heights Summary:

- Agrees well with
    - *Belfort Laser Ceilometer*
    - *MPL*

- Virga can be detected using
  vapor-liquid-aerosol channels
  (*see Demoz et al. GRL 2000*)

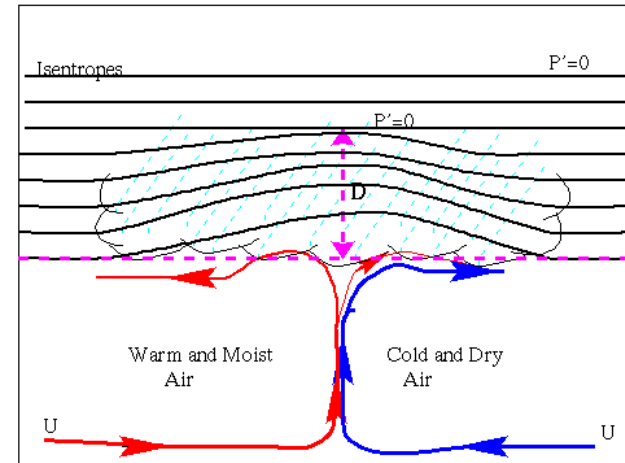- Depolarization can be used to better
  define virga regions (CARL)

*Raman Lidars
detect
Cloud Base Height
well*

==> Raman lidars can give Lifting depth, d_{max}**!!**
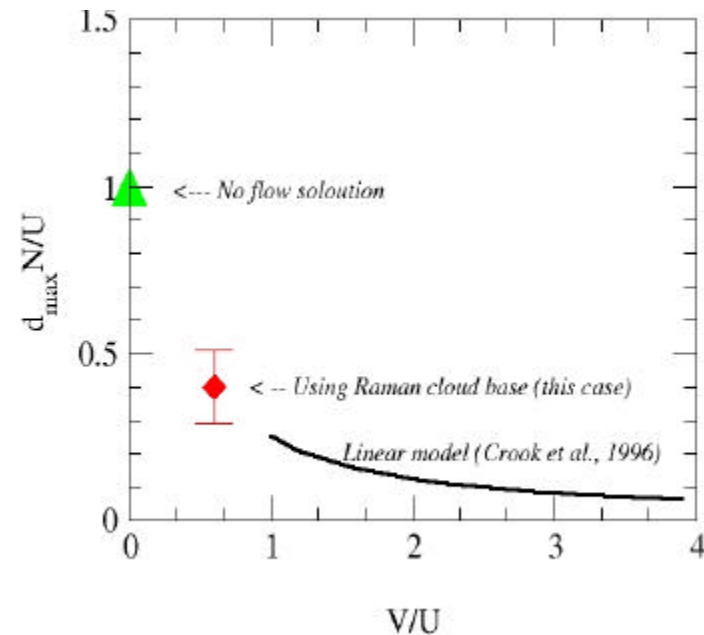
Theoretical Background

(see Crook and Klemp 2000)

- d_{max} maximum displacement

- V is flow above the boundary layer

- U maximum horizontal speed

- N is Brunt-Vaisala frequency

Prediction of D

- Works for V/U > 1
- Works for No-Flow above
- fails V/U < 1!!

*Raman lidars
can help fill this theoretical
gap!!*

Summary and Conclusion:

Boundary Layer Convergence Lines (BLCL) are key to understanding cloud and storm dynamics as well as forecasting these systems.

Raman Lidars can
- measure detailed water vapor and aerosol profile of BLCL
- visualize the dynamics of BLCL
- detect clouds
    - can identify BLCL
    - Cloud Base Height can be used as "lifting depth"
- fill where the linear theory fails and
- test the "physics" in the theory